Turbulent Microstructure Studies in Coastal Ocean Boundary Layers

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LONG-TERM GOALS

Our long term goal in this study is to obtain an extensive picture of turbulent mixing processes from near surface to near the bottom boundary layer at dissipation scales in conjunction with measurements of mixing from the injection of a tracer (Ledwell) and in the context of larger scale measurements in the Coastal Mixing and Optics study.

OBJECTIVES

The specific objective of the current year was to analyze data from the two field experiments in September 1996 and August 1997. In these two studies, measurements were obtained at a time of weak stratification after the passage of a hurricane (1996) and of late summer stronger stratification (1997). These were to be carried out in a joint experiment with Ledwell with microstructure profiles interspersed with tracer injection and sampling. The primary scientific objective was to compare mixing rates estimated by the dispersion of a tracer and inferred from microstructure measurements.

APPROACH

Microstructure data collection involved using the vertical profiling instrument EPSONDE in repeated profiles from the surface to near the bottom at the Coastal Mixing and Optics experimental site. The strategy was for Ledwell to inject a tracer on a specific density level and to map the area to obtain the initial conditions for the tracer. This was followed by our microstructure survey along the predicted track of the tracer as it advected with the measured currents. Tracer and microstructure surveys were interspersed over several days to follow the evolution of the dye.

WORK COMPLETED

The measurement of microstructure profiles, interspersed with dye injection and dispersion measurements, have now been completed for four depths and density gradients from two experiments in 1996 and 1997 done near the Coastal Mixing and Optics mooring site in about 70 meters of water. Two dye-microstructure studies completed by Ledwell and Oakey in the fall of 1996 were with rhodamine at mid-depth and fluorescein at about 50 meters. In 1997 injections were done at about 20 meters from the surface with rhodamine and at about 5 meters above bottom with fluorescein near the central mooring site of the Coastal Mixing and Optics experiment in water depth of about 70 meters. In excess of 2000 microstructure profiles have been analyzed and edited to obtain estimates of dissipation, ε, and temperature variance, χ_θ, and derived vertical diffusivities for each profile segmented in bins of about 1.8 meters from commonly used microstructure models. Initial attempts

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have been made to compare the integrated vertical diffusivity from the microstructure data with those obtained from the dye dispersion data obtained by Ledwell and these results were presented at the February 1998 San Diego ASLO meeting.

RESULTS

Microstructure data from all four dye-microstructure experiments have been analyzed and edited to provide estimated of the rate of turbulent mixing to compare with the estimates of mixing from the spreading of a tracer. As an example of the results, preliminary data from dye injection 2 (1996) at a depth of 45 meters ($\sigma_\theta = 24.3$) will be shown as an example of the data. Figure 1 shows the ship track of the microstructure profiles (in red) interspersed with the dye measurements (in green) in relation to the CMO main mooring (black dots)

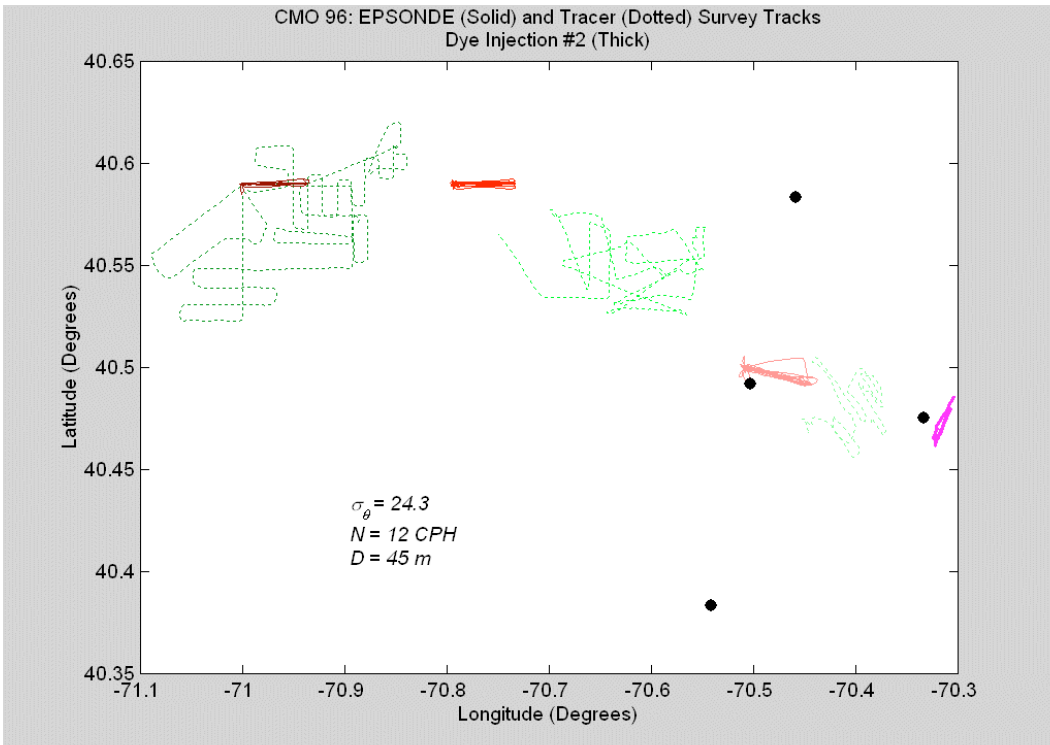

Figure 1: Microstructure and tracer measurements for the second injection in 1996.

The microstructure data were obtained in bursts of typically 20 to 30 profiles by successively dropping the instrument EPSONDE along a line of about 5-km as the ship steamed at about 2 knots. These data were averaged into profiles giving mean values and standard deviation for each burst for dissipation, ε, and temperature variance, χ_θ, as well as depth, density and vertical diffusivities. The diffusivities that matched the density surface of the tracer were found and used in integrating diffusivity to compare to the tracer. Mean density profiles are shown in Figure 2 to indicate the depth ranges over which data were selected. The diffusivity profile around the target isopycnal determined from these burst averaged station data is shown in Figure 3. The diffusivity determined for the temperature gradient microstructure K_T (blue) is larger than that obtained from the dye (green) although the range of the estimate of K_T and the range for the dye overlap. Diffusivity obtained from the dissipation (pink), assuming a mixing efficiency of 0.25, is larger than K_T and suggests that a lower value of mixing efficiency is appropriate.

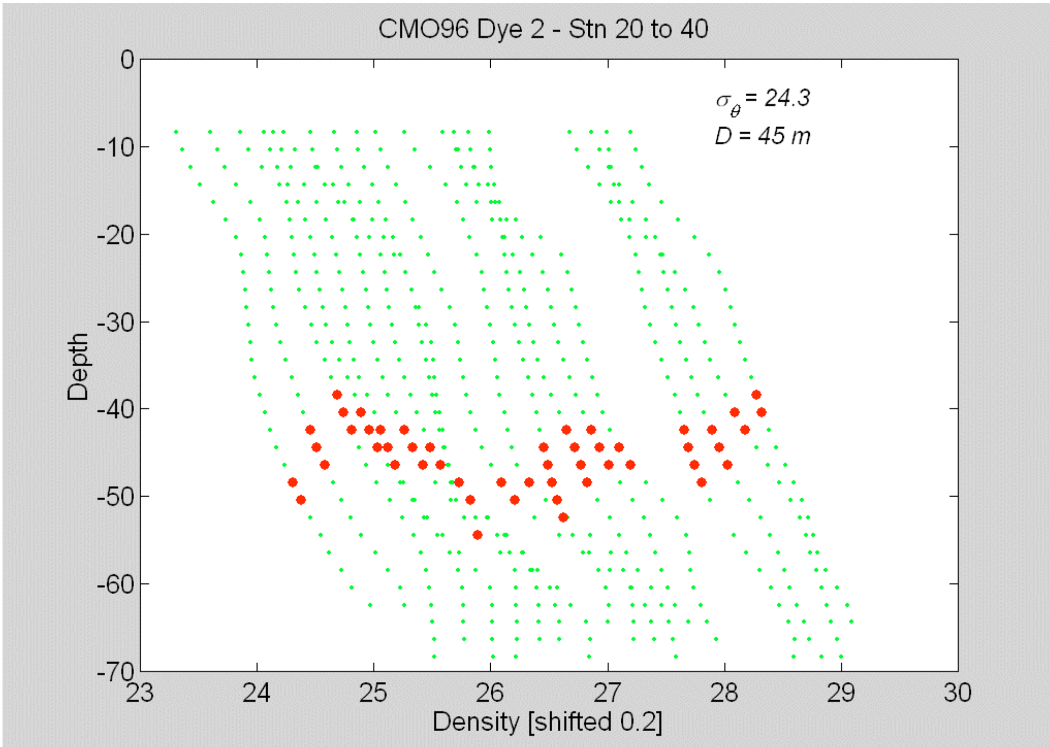

Figure 2: Waterfall plot of mean density profiles for dye injection 2 (1996) measured by EPSONDE where the sections of the profile indicated in red dots are used to calculate a diffusivity to compare to that determined by the dye. Each profile represents the average of 15 to 40 individual drops.

Our preliminary estimates of vertical diffusivity for all four dye injections are summarized in the table below.

Year	**Injection**	**Depth-meters**	σ_θ	**N - CPH**	**K_T- m^2/s**	**K_dye - m^2/s**
1996	1	32	24.06	5.7	059 x 10^{-4}	0.1 - 0.3x10^{-4}
	2	45	24.30	12	0.13	0.2 - 0.9
1997	1	20	24.60	18	0.058	0.01 - 0.04
	2	5 above bottom	26.14	20	0.049	0.02 - 0.09

It seems clear from the comparison of microstructure and dye estimates that the values agree at least within a factor of two from these preliminary estimates. The full data set is now being used to obtain final estimates and better error bars.

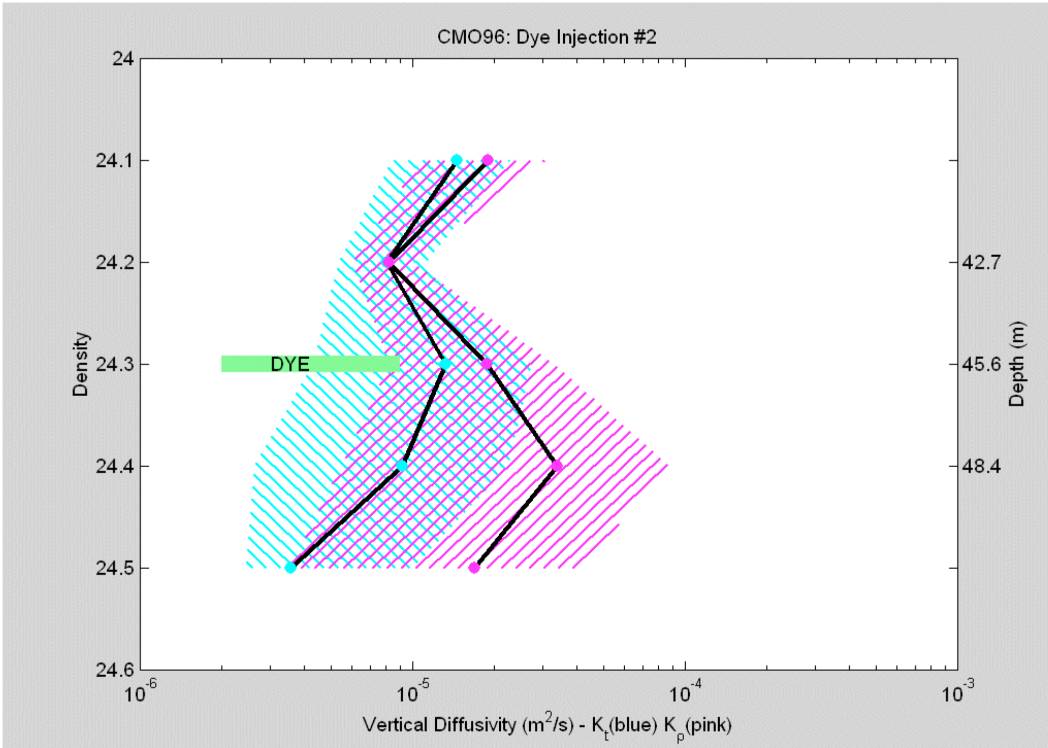

Figure 3: The diffusivity determined for the temperature gradient microstructure K_T is shown in blue with the diffusivity obtained from the dissipation assuming a mixing efficiency of 0.25 is shown in pink. The range of the diffusivity and its depth and density is indicated by the green line.

IMPACT/APPLICATIONS

This is the first time that tracer and microstructure measurements of mixing in the ocean have been done on the same length and time scales to test commonly used mixing models.

TRANSITIONS

RELATED PROJECTS

This study is part of the Coastal Mixing and Optics experiment in particular the turbulence results are being compared to those obtained by Jim Ledwell of WHOI.

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